REINSTATEMENT IN AN APPETITIVELY MOTIVATED PARADIGM

An abstract of a Thesis by
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The problem. To demonstrate reinstatement in an appetitively motivated paradigm within the limitations of Campbell and Jaynes' 1966 definition of that phenomenon, and to introduce a qualitatively distinct reinstatement treatment.

Procedure. Eighty-five 21-28 day old rats were randomly assigned to one of either three experimental or three control conditions. Subjects in the three experimental conditions were pretrained and trained to a criterion performance on a light-dark discrimination task in a Y-maze. At 7, 14, and 21 days thereafter they received reinstatements consisting of either two reinforced trials in the Y-maze (group I) or one reinforced and one non-reinforced trial in a specially prepared straight alley (group II) which presented the critical stimulus elements of original training in an altered context. Group III subjects served as retention controls and did not receive the reinstatements. Subjects in groups IV, V, and VI received the same treatments as those in groups I, II, and III (respectively) with the exception that they were not initially pretrained or trained in the Y-maze. Twenty-eight days after the initial session subjects in groups I, II, and III were retrained to criterion in the Y-maze while subjects in groups IV, V, and VI were pretrained then trained to criterion in the maze.

Findings. Simple main effects analyses within a split-plot factorial design established that the two reinstatement conditions produced significant retention of the discrimination with group I subjects showing slightly, although not significantly, better retention than group II subjects. Retention controls showed no retention of the discrimination. Analysis of groups IV, V, and VI showed no effect of the reinstatements *per se* on naive animals.

Conclusions. It was concluded that reinstatement could be demonstrated in an appetitive paradigm, and that it may occur regardless of whether the organism can be returned to the original learning environment.

Recommendations. Further study investigating stimulus parameters of reinstatement were suggested.

REINSTATEMENT IN AN APPETITIVELY

MOTIVATED PARADIGM

A Thesis

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by

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Chapter 1

INTRODUCTION

It has been demonstrated by a number of researchers that the age of a subject at the time of acquisition of a learned task is an important variable influencing the degree to which the learning of that task is retained. Weanling rats (18-26 days old at the time of acquisition) typically show impaired retention of passive avoidance learning when compared to rats which are of adult, or near adult, age (38 days and older) at the time of training. This age-related deficit has been demonstrated in a variety of shock motivated paradigms (Campbell & Campbell, 1962; Kirby, 1963) as well as in an appetitively motivated, bar-press discrimination paradigm (Campbell, Jaynes & Misanin, 1968). While the specific retention intervals differed in these studies the retention differences between age groups generally became significant once the retention interval lengthened to 21-25 days. These differences did not seem to be attributable to differences in the rate or degree of acquisition of the task by the younger subjects (Kirby, 1963).

Campbell and Campbell (1962) have generalized their findings to the childhood learning of fears or anxieties in humans. They noted that such learning is rapidly forgotten unless repetition of the original conditioning situation occurs. Campbell and Jaynes (1966) suggested that the above mechanism for preserving retention of early learning existed, and introduced the term reinstatement to describe it. Reinstatement was defined in the latter study as, "...a small amount of partial practice or repetition of an experience over the developmental period which is enough to maintain an early learned response at a high level, but is not enough to produce any effect in animals which have not had the early experience." (p. 478).

To demonstrate reinstatement Campbell and Jaynes (1966) divided 30 weanling rats into three experimental groups. The subjects in two of the groups were given discriminative fear training in a shuttle box by receiving 30 two sec shocks in the black compartment and no shocks in the white compartment. Escape or avoidance was prevented by a barrier placed between the compartments. The subjects in one of the groups were given reinstatements 7, 14 and 21 days after initial training. These consisted of a single two sec shock administered on a variable-time, 60 sec schedule (VT-60) in the black compartment and then holding the subject for an equivalent period of time in the white compartment with no shock. Subjects in the second group did not receive the reinstatements and served as retention controls. The third group did not receive the initial fear training but did receive the reinstatements. Twenty-eight days after acquisition all subjects were placed in the shuttle box with free access to both compartments. Mean percent time spent in the white compartment during this period served as the retention measure. Subjects which received the initial fear training and the reinstatements spent significantly more time in the white compartment than either retention controls or reinstatement controls (the third group). The enhanced retention displayed by reinstatement subjects over retention controls will hereafter be referred to as a reinstatement effect.

Shubat and Whitehouse (1968) replicated Campbell and Jaynes' 1966 study but, citing equipment factors as possible confounding elements, they included an additional pure control group which received only the retention test. Their results were consistent with those obtained by Campbell and Jaynes (1966). Several subsequent studies have extended reinstatement findings. Silvestri, Rorbaugh, and Riccio (1970), in two experiments, demonstrated that postacquisition exposure to the conditioned stimuli (CSs) of the apparatus with no unconditioned stimulus (US) presentation was sufficient to produce reinstatement effects; and, that the degree of retention enhancement was a function of the duration of CS presentation. Moderately brief (30 and 60 sec) presentations were found to be more effective in preserving retention than longer ones (300 and 900 sec). Rorbaugh and Riccio (1970) obtained the same curvilinear relationship between reinstatement cue duration and retention enhancement as

Silvestri et al. (1970). Greenfield and Riccio (1972) further extended the designs of Silvestri et al., and Rorbaugh & Riccio by including two experimental groups which received exposure to the CSs of only the previously shocked black compartment or the nonshocked white compartment. Retention testing revealed that exposure to only the black compartment or to both compartments produced a reinstatement effect, but that exposure to only the white compartment did not produce a reliable increment in retention over retention controls.

While there are minor differences in equipment and design among the preceding studies their results lead to several conclusions. First, within passive avoidance learning paradigms the reinstatement phenomenon is fairly robust. Second, reinstatement effects appear to be dependent upon exposure to the most directly relevant cues of the original learning situation. Finally, reinstatement seems to be a fairly subtle process since relatively brief re-exposures to the original learning cues produce a significant degree of protection against retention loss. Conclusions concerning the generality of the phenomenon are somewhat harder to draw. The demonstration of reinstatement has only occurred within passive avoidance learning paradigms. In addition, those demonstrations have used basicly the same equipment and experimental design. However, the most important issue for the development of this thesis is that reinstatement, as defined by Campbell and Jaynes (1966), has not been convincingly demonstrated within an appetitively motivated paradigm.

Campbell and Jaynes (1969) have investigated reinstatement in such a paradigm. They employed a bar-press response on a visual discrimination task as the basis for training and later retention measurement. Subjects (21-25 days old) were exposed to 18 hr sessions in a standard operant chamber on a multiple variable-interval 15 sec - extinction (MULT VI-15/EXT) schedule for four consecutive days. Control subjects were placed in holding cages for equivalent periods of time. Reinstatements were delivered once a week for ten weeks thereafter, and consisted of 0, 7.5, 15, 30, or 60 min re-exposures to the MULT VI-15/EXT schedule in the operant chamber. Retention testing consisted of 24 hr retraining sessions for half the experimental and control subjects, and 24 hr extinction sessions for the other half. Their results were generally consistent with a demonstration of reinstatement effects. However, since the reinstatement durations (7.5, 15, 30, and 60 min) which preserved retention of the discrimination also seemed to produce a degree of learning in control subjects, their results are considered to be equivocal. This conclusion is based on their figures for retention test performance and is difficult to evaluate properly since the statistical analysis included in their report was inadequate. In summary, then, it would not appear that Campbell and Jaynes (1969) were entirely successful in demonstrating reinstatement in an appetitively motivated paradigm within the limitations of their original (1966) definition which requires that the reinstatements produce <u>no</u> learning in naive control animals.

The author believes that most of the problems in interpreting Campbell and Jaynes' 1969 study were related to the nature of the task employed. Since subjects had to be trained over a period of four days it is likely that they entered the reinstatement phase with differing levels of performance on the discrimination.[1] In addition, the reinstatements were rather lengthy and probably differed across subjects as a function of differing response rates. Further, the unusually long retention interval (70 days) may have contributed to learning in control subjects since they would have attained essentially adult physiological status by the 55th day of age.[2] This would have coincided, approximately, with the fourth of the ten reinstatements and could have enhanced retention of any learning which occurred during

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[1] Campbell, Jaynes and Misanin (1968) had discarded 25% of their 23-26 day old subjects because they had failed to reach a 80% discrimination criterion in 120 hrs of continuous training on an identical task.

[2] For information relating to this assertion see Aghajanian and Bloom (1967), Jacobson (1970), Karki, Kuntzman and Brodie (1962), Kato (1960), or Metzler and Humm (1951).

subsequent reinstatements.

A more convincing demonstration within an appetitively motivated paradigm should incorporate the following features. The task selected should allow for rapid acquisition to minimize the effects of age changes during training, and allow for a criterion cut-off point to level subjects performance prior to the delivery of reinstatements. In addition the task should allow for direct comparison of the performances of reinstatement as opposed to retention control subjects, and for the accurate assessment of any learning which may occur in naive animals. Finally, the task should allow for control of the comparability of reinstatements across subjects, and for the delivery of discrete, brief reinstatements. The latter feature, in particular, is regarded as a necessary condition for a successful demonstration of reinstatement.

A pilot study was initiated in Spring 1974 which incorporated most of those features. Thirty-six male, Long-Evans hooded rats were randomly assigned to three experimental groups designated as reinstatement, retention control, and reinstatement control. At 24-27 days of age the subjects in the reinstatement and retention control groups were given ten reinforced trials in a straight alley as pretraining and then were immediately trained for food reinforcement to a criterion of 9/10 consecutive correct trials on a light-dark discrimination (with light as the S+) in a

Y-maze. At 7, 14, and 21 days thereafter each subject in the reinstatement group received two reinforced trials in the Y-maze with original training procedures in effect. Subjects in the retention control group were simply deprived and given equivalent handling at the same intervals. Twenty-eight days after training subjects in the reinstatement and retention control groups were retrained to criterion in the Y-maze employing original training procedures. Trials and errors to criterion were recorded for both phases. Subjects in the reinstatement control group received pretraining only in the initial stage, and then received the same reinstatements at the same intervals as the reinstatement group. They were also trained to criterion in the fourth week and the same measures were collected.

The principal results of the study were fairly clear cut. Subjects in the retention control group required a mean of 38.3 trials to reach criterion in original training, and required a mean of 42.6 trials to re attain criterion performance in relearning. Subjects in the reinstatement group required a mean of 50.8 trials to initially learn the discrimination, but only required a mean of 23.6 trials to reattain criterion performance. The data for both trials and errors were tested statistically by a split-plot factorial analysis utilizing an unweighted means solution. Tests for simple main effects revealed a highly significant effect ($p < .01$) of the reinstatement in preventing loss of the discrimination. While no other effects were statistically significant the differences between the reinstatement and retention control groups on original learning measures were nearly so ($.05 < p < .10$).

It was evident after the experiment that a fourth control group was necessary for the analysis of the effect of the reinstatements on the naive control animals. Nonetheless, it was felt that despite this difficulty the main effects of the reinstatement in enhancing retention of the discrimination were sufficiently powerful to warrant a second study representing both a replication and extension of this initial pilot research. The replication, in any case, was desirable in order to obtain a more accurate measure of the reinstatements' effects on the naive subjects, and because of the relative disparity between reinstatement and retention control subjects on original learning measures (which unexpectedly confounded the main analysis.) The nature of the extension was determined through the following rationale.

It is seldom the case in the world outside of the laboratory that the conditions under which the original acquisition of some learned task may be replicated <u>in toto</u> at a later date. Organisms frequently change, or are forced to change, the environmental settings in which they live and behave. Despite this they are usually expected, or required, to respond appropriately to discriminative cues in their new environments on the basis of learning acquired in the past and in different contexts. This implies that the memory of that learning must remain active or retrievable. As has been noted juvenile organisms frequently do not display a capacity for retention of early learning unless a process such as reinstatement intervenes. The demonstration of reinstatement, however, has depended upon returning the juvenile organism to its original learning environment at periodic intervals. Such periodic returns may be frequently impossible in "real world" situations because of the changes in environment noted above. Therefore, including reinstatement as a general mechanism for preserving memory retrieval (cf., Spear, 1973) requires a demonstration that brief re-exposures to the essential elements of original learning in contexts altered from those under which that learning occurred can produce a reinstatement effect. Accordingly, the purpose of this thesis was to introduce a qualitatively distinct reinstatement treatment and examine its effects along with the effects of the more traditional reinstatement treatment in the remediated design of the pilot study.

Chapter 2

METHOD

Subjects

Subjects were 85 male, Long-Evans hooded rats obtained from a commercial supplier in three consecutive batches. All subjects were 16-18 days of age when received at the laboratory and were housed in individual stainless steel cages. The colony room was maintained on the same artificial light-dark cycle (7 A.M. to 7 P.M.) at all times. Subjects were maintained on *ad libitum* food and water at all times with the exception that they were deprived of food 24 hrs prior to any experimental session. All subjects were 21-28 days of age at the onset of training.

Apparatus

The basic equipment used consisted of a plain straight alley used for pretraining, a Y-maze, and a specially prepared straight alley used for one reinstatement condition.

The pretraining alley was constructed of grey painted wood (internal dimensions: 4 1/4 in wide X 6 in high X 47 3/4 in long) and roofed with clear plexiglass. Guillotine doors were located 12 in from each end wall and a plastic food cup was provided at each end. The Y-maze was also constructed of grey painted wood and had three identical arms spaced at equal angles to each other. Each arm of the maze (internal dimensions: 5 3/4 in wide X 5 3/8 in high X 18 in long) had a backwall constructed of a 1/4 in thick, translucent white plexiglass panel behind which a standard 15 watt housebulb was mounted to serve as the discriminative stimulus. Each arm was equipped with a plastic food cup, and had a guillotine door located 11 in from its backwall. The maze was roofed with clear plexiglass except for the portion of each arm from backwall to door which had a hinged masonite cover. The maze was anchored, as a unit, to a plywood sheet which was placed on a table and a 25 watt housebulb was suspended 38 in over the maze center for house illumination.

The reinstatement straight alley was constructed to be similar in its dimensions to the arms of the Y-maze. This maze was also constructed of grey painted wood (internal dimensions: 5 3/4 in wide X 5 3/8 in high X 36 in long--the length of two arms in the Y-maze) with backwalls of plexiglass identical to those in the arms of the Y-maze. A 15 watt housebulb was also located behind each backwall to serve as the discriminative stimulus. A guillotine door was located 11 in from each backwall and the alley was roofed with clear plexiglass between the doors. Hinged covers of pine board covered each end of the alley from backwall to door.

When in use each of the alleys was placed on the table under the 25 watt bulb. Food reinforcement consisted of 20 mg Noyes pellets.

Procedure

Due to the large number of subjects employed and the time required to run the study it was accomplished as a series of three complete replications. During each replication the procedure remained the same and is summarized in Table I below. Upon arrival at the laboratory each batch of subjects was randomly assigned to one of the six experimental groups. When the subjects reached 21-23 days of age the experiment was initiated. Subjects in the maze reinstatement (I), straight alley reinstatement (II), and retention control (III) groups were given ten reinforced trials in the straight alley as pretraining, and then were immediately trained in the Y-maze to the same criterion as used in the pilot study. Subjects were required to run to the lighted (S+) arm of the maze to receive one food pellet. Each goal box automatically became the start box for the next trial and eliminated the necessity of handling the subjects once in the maze. A 30 sec intertrial interval was employed to promote uniformity of running procedures and to randomize the effects of the subjects position at the start of a trial. The reinforced arm location (L-R) was varied randomly on a schedule which controlled for position preferences and the number of reinforcers obtained in each arm. Errors were defined as crossing both forepaws across a straight line drawn across the mouth of the S- arm and touching the floor of that arm. A correction procedure was in effect such that if the

TABLE I

Treatments delivered according to experimental condition and phase: PT-T = pretraining + training; RT = retraining; MA = maze reinstatement; SA = straight alley reinstatement; DH = deprivation and handling

Group	Initial	R_1	R_2	R_3	Final
Maze Reinstatement (I)	PT-T	MA	MA	MA	RT
Straight Alley Reinstatement (II)	PT-T	SA	SA	SA	RT
Retention Control (III)	PT-T	DH	DH	DH	RT
Maze Control (IV)	DH	MA	MA	MA	PT-T
Straight Alley Control (V)	DH	SA	SA	SA	PT-T
Age Control (VI)	DH	DH	DH	DH	PT-T

subject committed an error on any trial the door to the start box was lowered and the subject was allowed free movement in the maze until entering the S+ arm and terminating the trial. The number of trials and errors required to reach criterion, and latencies per trial were recorded for each subject.

Reinstatement trials for each of the subjects in the maze and straight alley reinstatement groups were administered on the 7th, 14th, and 21st day following original training. Reinstatements for the group I subjects consisted of two reinforced trials in the Y-maze with original training procedures in effect. Reinstatements for group II subjects consisted of one reinforced (subject was required to run to the lighted end) and one non-reinforced (subject was required to run to the dark end) trial in the reinstatement straight alley. Errors and latencies were recorded wherever possible. Subjects in group III did not receive any of the reinstatements but were deprived simultaneously with groups I and II and given as exact an equivalent of handling as possible.

Retention testing for each subject occurred 28 days after the termination of original training. Subjects in groups I, II, and III were retrained to criterion in the Y-maze in accordance with original training procedures. The same performance measures were obtained.

Subjects in the maze control (IV), straight alley control (V), and age control (VI) groups received the same treatments as subjects in groups I, II, and III (respectively) with two major exceptions. They were not pretrained or trained to criterion in the initial stage but only received exact equivalents for deprivation and handling. Then, 28 days after their initial deprivation, they were pretrained in the plain straight alley and trained to criterion in the Y-maze with duplication of the procedures used for the original training of subjects in groups I, II, and III.

Due to the sheer number of subjects involved it was impossible to initiate the experiment for all subjects at 21-23 days of age. Differences at age of onset, however, were proportionally represented across groups. Precautions were taken to insure that time of day for each successive experimental treatment remained a constant for each subject, and that subjects within analysis groupings (maze reinstatement, straight alley reinstatement, and retention control vs. Maze control, straight alley control, and age control) were run closely enough in time to minimize the possibility of circadian activity effects contaminating the various measures. A discard criterion (derived from experience in the pilot) was employed such that if a subject froze for ten consecutive minutes in either the pretraining alley or Y-maze (regardless of experimental phase) they were removed from both the equipment and the analysis.

Chapter 3

RESULTS

The results will be dealt with successively in terms of main analysis groups (I, II, and III) and control analysis groups (IV, V, and VI) since their data were treated separately.

Main Analysis

The experiment was constructed as a split-plot factorial design. The analysis assigned the maze reinstatement, straight alley reinstatement, and retention control conditions to levels a_1, a_2, and a_3 (respectively) of the independent variable A. Initial Y-maze training and retraining were assigned to levels b_1 and b_2 (respectively) of the repeated measures variable B. The analysis was performed separately for trials-to-criterion and errors-to-criterion, and employed an unweighted means solution because of unequal cell numbers due to normal loss through death or disease.

Overall ANOVA results

Summary statistics and the results of the analysis for trials are available for inspection in Tables II and III below. The data in Table II show that the subjects in the maze reinstatement and straight alley reinstatement conditions showed a considerable decrease in the average number of trials required to reattain criterion. Subjects in the retention control condition required the same number of trials, on the average, to relearn the discrimination as they took to learn it originally. The overall ANOVA did not reveal a significant effect of reinstatement condition (F_A, $P > .18$), but did reveal a significant effect for learning phase (F_B, $P < .001$) and for the learning phase--reinstatement condition interaction (F_{AB}, $p < .04$).

TABLE II

Mean trials to criterion arranged according to reinstatement condition and learning phase

	Learning Phase	
	original	relearn
Maze (I)	n=11 38	n=11 20.27
Straight Alley (II)	n=13 40.08	n=13 25.15
Retention Control (III)	n=12 36.33	n-12 36.75

TABLE III

Results of the overall ANOVA for trials-to-criterion

Source	SS	df	MS	F	P
A	655.599	2	327.799	1.776	0.1852
S_{wg}	6091.7	33	184.597		
B	2069.05	1	2069.05	14.113	0.00067
AB	1140.27	2	570.135	3.89	0.0304
B x S_{wg}	4837.99	33	146.606		

The results for errors paralleled those for trials and are displayed in Tables IV and V. Table IV shows that subjects in the two reinstatement conditions required considerably fewer errors to reattain criterion. Subjects in the retention control group required the same mean number of errors (within one unit of measurement) to relearn the discrimination as they took to learn it originally. The overall ANOVA did not reveal a significant effect for reinstatement condition ($p_A > .10$), but did reveal a significant effect for learning phase ($p_B < .003$) and for the learning phase - reinstatement condition interaction ($p_{AB} < .05$).

The presence of a significant interaction between learning phase and reinstatement condition for both trials and errors indicated that an analysis for simple main effects was warranted for each measure.

TABLE IV

Mean errors-to-criterion arranged according to reinstatement condition and learning phase

	Learning Phase	
	original	relearn
Maze (I)	n=11 20.36	n=11 8.18
Straight Alley (II)	n=13 21.85	n=13 11.38
Retention Control (III)	n=12 20.08	n=12 19.17

TABLE V

Results of the overall ANOVA for errors-to-criterion

Source	SS	df	MS	F	P
A	344.32	2	172.16	2.4004	.106
S_{wg}	2366.63	33	71.72		
B	1104.85	1	1104.85	16.982	.0024
AB	440.46	2	220.23	3.385	.046
B x S_{wg}	2146.9	33	65.06		

Simple Main Effects Results

The results for the simple main effects analysis for trials are displayed in Table VI. The mean values in Table II show that there were very minor differences in the mean number of trials required to reach criterion between the maze reinstatement, straight alley reinstatement, and retention control groups in the original learning phase. The F test for A at b_1 confirmed that these differences did not approach significance ($p > .76$). The F test for A at b_2, however, demonstrated that there were highly significant differences (assigned $p < .02$) between the three groups in relearning. The tests for the effects of B at the various levels of A revealed the extent to which the AB interaction in the overall analysis obscured the effects of the reinstatements. The F test for B at a_1 confirmed that the maze reinstatement condition produced a highly significant (assigned $p < .005$) decrease in the mean number of trials required to relearn the discrimination. The F test for B at a_2 verified that the straight alley reinstatement condition also produced a quite significant decrease (assigned $p < .011$) in the mean number of trials required to reattain criterion. The F test for B at a_3 supported the observation that retention control subjects required the same (within one unit of measurement) average number of trials to relearn the discrimination as they took to learn it originally ($p = .933$).

TABLE VI

Simple main effects analysis for trials-to-criterion

Source	SS	df	MS	F	P
A at b_1	88.05	2	44.03	.266	.767
A at b_2	1672.85	2	836.43	5.051	.0091
S_{wcell}	10929.69	66	165.6		
B at a_1	1728.41	1	1728.41	11.789	.0016
B at a_2	1447.54	1	1447.54	9.874	.0035
B at a_3	1.04	1	1.04	.007	.933
B x S_{wg}	4837.99	33	146.06		

The results of the simple main effects analysis for errors directly paralleled those for trials and are displayed in Table VII below. As was the case for trials the tests for A at b_1 and b_2 confirmed that there were no significant differences (p=.849) between the maze reinstatement, straight alley reinstatement, and retention control subjects in original learning, but that there were highly significant differences (assigned $p < .02$) between the three groups in the relearning phase. The tests for B at the various levels of A verified that there were highly significant decreases in the mean number of errors to reattain criterion in the maze reinstatement (assigned $p < .004$), and straight alley reinstatement (assigned $p < .007$) conditions, but that retention controls displayed no significant differences between learning phases ($p=.782$). The differences in performance in relearning confirmed by the simple main effects analyses are graphically displayed for trials and errors in Figure 1. That figure illustrates that there were differences not only between the reinstatement and retention control groups, but between the reinstatement groups as well. The maze and straight alley reinstatement groups, however, did not differ significantly for mean proportion of either original trials or errors required to relearn the discrimination ($t_{trials} = .926$, $p > .30$; $t_{errors} = .944$, $p > .30$).

TABLE VII

Simple main effects analysis for errors-to-criterion

Source	SS	df	MS	F	P
A at b_1	22.48	2	11.24	0.164	.849
A at b_2	745.62	2	372.81	5.451	.0064
S_{wcell}	4513.53	66	68.39		
B at a_1	816.18	1	816.18	12.45	.0012
B at a_2	711.38	1	711.38	10.934	.0023
B at a_3	5.04	1	5.04	.078	.782
B x S_{wg}	2146.90	33	65.06		

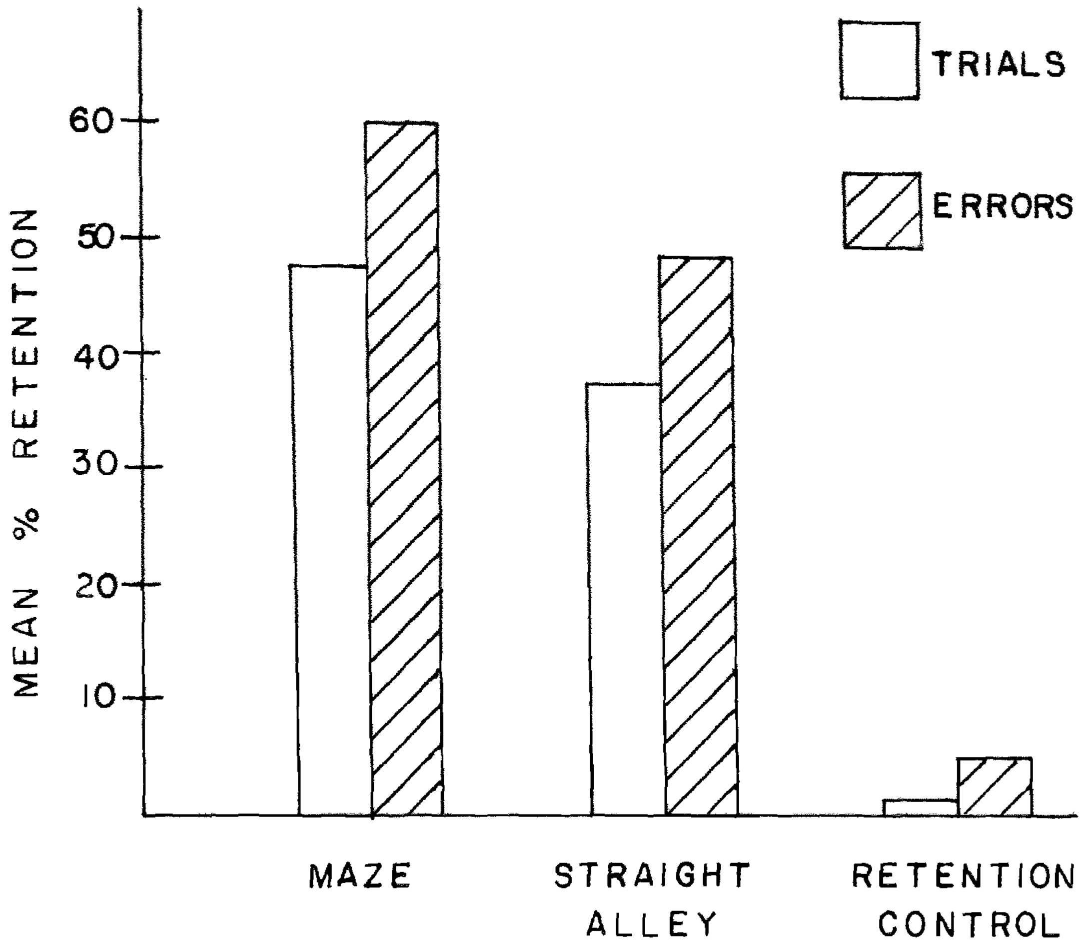

Figure 1.

Mean percent retention of original learning as a function of reinstatement condition and dependent variable measure.

Subsidiary Data

The differences between reinstatement and retention control subjects on primary measures were paralleled by other measures. Due to the correction procedure used in discrimination training subjects could, and did, commit multiple errors on some trials. A summary of the data for multiple errors is displayed in Table VIII which shows that the direction of change in relearning for mean number of trials with multiple errors was ordered for the three groups as the changes in primary dependent variable measures were. A frequency distribution of the number of trials required to reattain criterion also underscores the differences between the three groups and is displayed in Table IX. The data in that table indicates that three of the reinstatement subjects failed to show any warm-up decrement in relearning (ten trials being the minimum required to reattain criterion), while five more reinstatement subjects showed only a minimal warm-up decrement. It should be pointed out that the latter five subjects committed their errors almost exclusively within the first three to five trials of the relearning series. This was clearly not the case for retention control subjects which repeated their error patterns displayed in original learning.

TABLE VIII

A summary of trials in which multiple errors were committed, ordered by condition and learning phase

	Maze Reinstatement		Straight Alley Reinstatement		Retention Control	
	original	relearn	original	relearn	original	relearn
Sum	34	9	46	30	37	35
Mean	3.09	.818	3.54	2.31	3.08	2.92
% Change	73.5		34.8		5.3	

TABLE IX

Number of trials required to reattain criterion as a function of reinstatement condition

Trials	Maze	Straight Alley	Retention Control
$\leq$ 11	1	2	0
$\leq$ 13	1	1	0
$\leq$ 15	3	0	0
$\leq$ 17	3	0	0
$\leq$ 19	1	0	0
> 20	2	10	12

Control Analysis

The measures obtained from the control groups did not allow for more than a comparison of means. Accordingly Dunn's Multiple Comparison Procedure was used to test all possible mean differences between the maze reinstatement control (IV), straight alley reinstatement control (V), and age control (VI) groups. The means for trials and all mean differences for that measure are displayed in Table X. The table shows that the differences that existed between the groups were slight and occurred primarily where one of the reinstatement control groups was compared to the age control group. None of the differences approached significance (lowest $d_{.05} = 14.24$).

TABLE X

Mean trials to criterion for control groups and all mean comparisons for that measure

Means

IV	V	VI
n=10	n=11	n=8
34.6	34.63	31.00

Mean Differences

	IV	V	VI
IV	-	.03	3.6
V	-	-	3.63
VI	-	-	-

A display similar to that for trials is available for errors in Table XI. As that display indicates the mean differences between the three groups were slightly larger for errors than those for trials in Table X. None of the differences approached signigicance however (lowest $d_{.05} = 10.36$).

TABLE XI

Mean errors to criterion for control groups and all mean comparisons for that measure

Means

IV	V	VI
n=10 23.40	n=11 24.55	n=8 18.50

Mean Differences

	IV	V	VI
IV	-	1.15	4.90
V	-	-	6.05
VI	-	-	-

The direction of any differences that existed between control groups was toward reinstatement control subjects requiring a slightly greater number of trials and errors to learn the discrimination than age control subjects.

There were differences between control groups in the final number of subjects which contributed data. This was primarily a result of an unequal distribution of deaths and cases of disease across the groups. Subjects were removed from each group in accordance with the discard rule, however this occurred proportionally across groups.

Chapter 4

DISCUSSION

Campbell and Jayne's 1966 definition of reinstatement requires that a study must be able to satisfy three essential requirements before a demonstration of reinstatement can be claimed. First, retention controls must display a noticeable deficit in retention of the learned task at the end of the retention interval. Second, administration of the reinstatement(s) must provide significant protection against the loss of the learned task demonstrated by the retention controls. Finally, the reinstatement(s) must not produce a noticeable degree of learning in naive control animals. These points, as they relate to this study, will be dealt with successively.

The performance of the retention control subjects established that the first requirement of the above definition was met. Those subjects required an almost identical number of trials and errors to relearn the discrimination as they took to learn it originally. Thus, despite the sensitivity of the savings method for testing retention, the retention control subjects displayed no apparent retention of the discrimination at the end of the 28 day interval. This was decidedly not the case for the subjects in the maze and straight alley reinstatement conditions. Subjects in the maze reinstatement condition displayed significant savings for both trials and errors to relearning, 47% and 60% respectively, and subjects in the straight alley reinstatement condition had significant savings of 37% and 48% for trials and errors to relearn. In addition the close similarity in the performance of reinstatement and control subjects during original learning, rule out the possibility that the retention differences observed were artifacts of differential learning in initial training. Those results unequivocably establish that either of the two reinstatements provided a significant degree of protection against loss of the learned discrimination. One of the more impressive aspects of the results is the observation that normal warm-up decrement can account for all of the errors committed by five of the reinstatement subjects during the retention test. Moreover, the reinstatements apparently eliminated <u>any</u> warm-up decrement in three subjects. This occurred despite the quite brief durations of re-exposure to learning elements afforded by the reinstatements.

It is further noted that a reinstatement effect was obtained where the re-exposures to the essential elements of original learning occurred in a context considerably altered from that in which the original learning took place. Indeed, the formal indications (based on the t-tests for retention differences between maze and straight alley reinstatement subjects) are that such re-exposures are as effective in preventing retention loss as brief replications of training in the original learning environment. It is evident, therefore, that either of the two reinstatements satisfied the second, and principal, requirement of Campbell and Jayne's (1966) definition.

The third requirement, which presented the major difficulty in interpreting Campbell and Jayne's 1969 study, was met as well. The differences in dependent variable measures between control groups of naive subjects were trivial. Indeed, the differences that did exist originated from reinstatement control subjects requiring slightly more, not fewer, errors and trials to learn the discrimination than the age control subjects did. It should be apparent, therefore, that either of the reinstatements *per se* did not produce any learning of the task in naive control animals.

The results of the study firmly establish that reinstatement effects can be demonstrated in an appetitively motivated paradigm within the limitations of Campbell and Jayne's 1966 definition. In addition, the results establish that reinstatement is not dependent upon periodic return to the exact contexts of original learning, but may occur in environmental situations which differ to a considerable degree from those in which that original learning occurred. The probability of reinstatement operating in the real world is commensurately increased. Juvenile organisms may be removed from their early learning environments completely but still retrieve the memory of learning acquired in those environments because of exposure to reinstating cues in their new, and dissimilar, living situations. In addition they may retain that memory in their new living situations just as effectively as they could have in their original environment. This (outside of it's obvious adaptive significance) is interpreted as a rather powerful argument for advancing reinstatement as a general phenomenon within developmental memory processes.

A note of caution should be entered here, however. The fact that there were no significant differences between the maze and straight alley conditions in retention of the task may have been due to the atypical performance displayed by two of the maze reinstatement subjects. These two subjects required a considerably higher number of trials and errors to relearn the discrimination than they took to learn it originally. The direction of differences which otherwise existed were toward maze reinstatement subjects showing superior retention over straight alley reinstatement subjects. It is possible, therefore, that replication may not support the equality of the two treatments in preventing retention loss. In addition it is impossible to evaluate whether appropriate reinforcement of behavior during reinstatements is a necessary condition for obtaining reinstatement effects within appetitive learning. It is conceivable that in a natural environment the discriminative cues for some early learned task may not be presented along with subsequent reinforcement for the appropriate behavior in their presence. Whether reinstatement effects can occur in such a situation cannot be determined on the basis of the present study. The issue is not a critical one for the present study, however, it would be worthwhile to determine if reinstatement effects can be demonstrated in an appetitive paradigm where presentations of only the discriminative cues serve as the reinstatements.

REFERENCES

Aghajanian, G. K., & Bloom, F. E. The formation of synaptic junction in the developing rat brain: a quantitative electron microscopic study. Brain Research, 1967, 6, 716-727.

Campbell, B. A., & Campbell, E. N. Retention and extinction of learned fear in infant and adult rats. Journal of Comparative and Physiological Psychology, 1962, 55(1), 1-8.

Campbell, B. A., & Jaynes, J. Reinstatement. Psychological Review, 1966, 73(5), 478-480.

Campbell, B. A., & Jaynes, J. Effect of duration of reinstatement on retention of a visual discrimination learned in infancy. Developmental Psychology, 1969, 1(2), 71-74.

Campbell, B. A., Jaynes, J., & Misanin, J. R. Retention of a light-dark discrimination in rats of different ages. Journal of Comparative and Physiological Psychology, 1968, 44(2), 467-472.

Greenfield, H., & Riccio, D. C. Conditioned reinstatement in rats: effects of exposure duration and type of cue. Psychological Reports, 1972, 31, 79-83.

Jacobson, M. Developmental neurobiology. New York: Holt, Rinehart and Winston, Inc., 1970.

Karki, N., Kuntzman, R., & Brodie, B. B. Storage, synthesis and metabolism of monoamines in the developing brain. Journal of Neurochemistry, 1962, 9, 53-58.

Kato, R. Serotonin content of the rat brain in relation to sex and age. Journal of Neurochemistry, 1960, 5(2), 202.

Kirby, R. H. Acquisition, extinction and retention of an avoidance response in rats as a function of age. Journal of Comparative and Physiological Psychology, 1963, 56(1), 158-162.

Metzler, C. J., & Humm, D. G. The determination of cholinesterase activity in the whole brains of developing rats. Science, 1951, 113, 382-383.

Rorbaugh, M., & Riccio, D. C. Paradoxical enhancement of learned fear. Journal of Abnormal Psychology, 1970, 75(2), 210-216.

Shubat, E. E., & Whitehouse, J. M. Reinstatement: an attempt at replication. Psychonomic Science, 1968, 12(5), 215-216.

Silvestri, R., Rorbaugh, M., & Riccio, D. C. Conditions influencing the retention of learned fear in young rats. Developmental Psychology, 1970, 2(3), 389-395.

Spear, N. E. Retrieval of memory in animals. Psychological Review, 1973, 80(3), 163-194.